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Originals

Monocarpic Mass Flowering and Flower Morphology of *Phyllostachys meyeri* McClure (Poaceae: Bambusoideae) Cultured in the Fuji Bamboo Garden, Japan

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Phyllostachys meyeri McClure cultivated in the Fuji Bamboo Garden, Japan showed monocarpic mass flowering from February through June 2004. In February, a majority of culms bore flower buds on their twigs. In March, flowering started with foliage leaves turning yellow. In April, the bamboos were in full bloom along with the shedding of all leaves. In June, they formed infructescences. At the same time, some slender, short, regenerated bamboos emerged with all their twigs bearing flower buds. Mature inflorescences were capitate with 12–20 pseudospikelets that showed indeterminate inflorescences. The average length of pseudospikelet, lemma, and anther were 9 mm, 8.2 mm, and 5.2 mm, respectively. Inflorescences of the regenerated culms were lax, with elongated peduncles and pedicels and lacked a foliaceous bract. Culm-sheaths of the flowering culms were entirely glabrous with small, smoky coloured spots. The rhizome had air canals. These characteristics suggested that *P. meyeri* was a member of section Heteroclada.

Key words: capitate inflorescence, monocarpic mass flowering, *Phyllostachys meyeri*, pseudospikelet, section Heteroclada.

Phyllostachys meyeri McClure was introduced to the United States of America from China by Mr. Frank N. Meyer. It was described by McClure (1945) based only on the morphology of the vegetative organs but no description of the flowers has been recorded. Wang et al. (1980a, 1980b) classified the Chinese *Phyllostachys* species into two sections, Phyllostachys and Heteroclada; *P. meyeri* is included in the former.

In the middle of February 2004, a monocarpic mass flowering of *Phyllostachys meyeri* occurred in the Fuji Bamboo Garden. We provide a precise description of the process of flowering and the morphology of the reproductive organs of *Phyllostachys meyeri* in this report.

Material and Methods

Phyllostachys meyeri McClure was maintained in the Fuji Bamboo Garden located at Nagaizumi, Shizuoka Prefecture, Japan; the collection was provided in 1990s by Mr. G. Bol, the president of the American Bamboo Society.

The bamboo clump comprising approximately 150 culms stood in an area of 32 m^2 in the garden. Average culm height, diameter and internode length were 502 cm, 2.2 cm, and 22.1 cm, respectively. From February

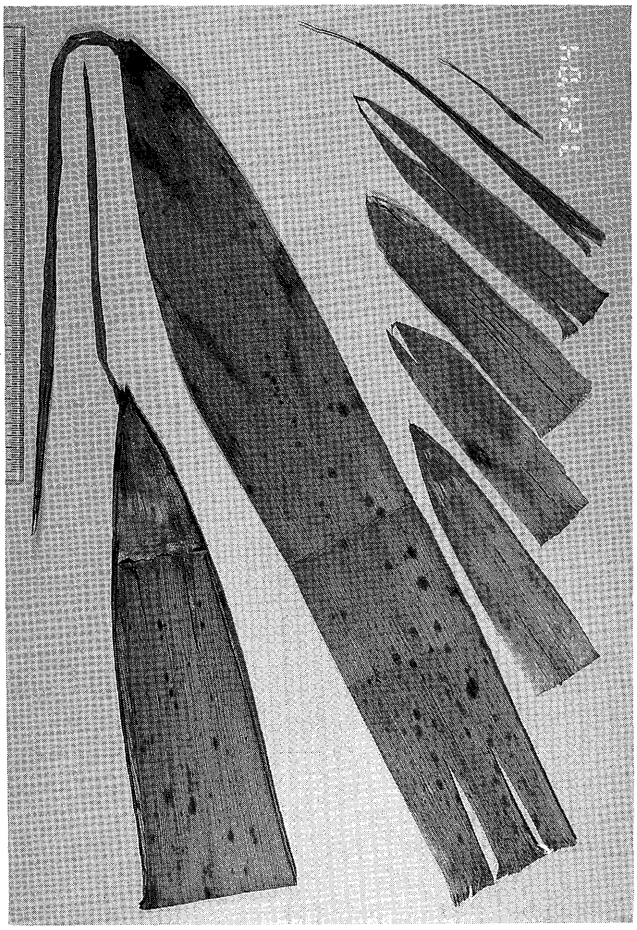

Fig. 1. Culm-sheaths of *Phyllostachys meyeri* collected from the Fuji Bamboo Garden on June 27, 2004; Hisamoto & Kobayashi 345. Left-hand side: lower one. center: upper one. right-hand side: six sheaths collected from a regenerated culm.

through June of 2004, the culms showed monocarpic mass flowering.

Flowering material was collected on February 21, March 15, April 18 and June 27 in 2004. The collected materials included; a whole culm, inflorescences, and rhizome system (Hisamoto & Kobayashi 346) in February, inflorescences in March (Hisamoto & Kobayashi 347) and April, and infructescences (Hisamoto & Kobayashi 348) and a regenerated culm with inflorescences (Hisamoto & Kobayashi 349) in June. We examined their morphological attributes in detail under 7–20 magnification with a dissection microscope.

We collected some culm-sheaths of *P. meyeri* (Fig. 1, Hisamoto & Kobayashi 345) from the understory of the mass-flowering clump, which provided adequate details to obtain more information about the species named by McClure (1945). Culm-sheaths are oblong, rather abruptly rounded at the apex,

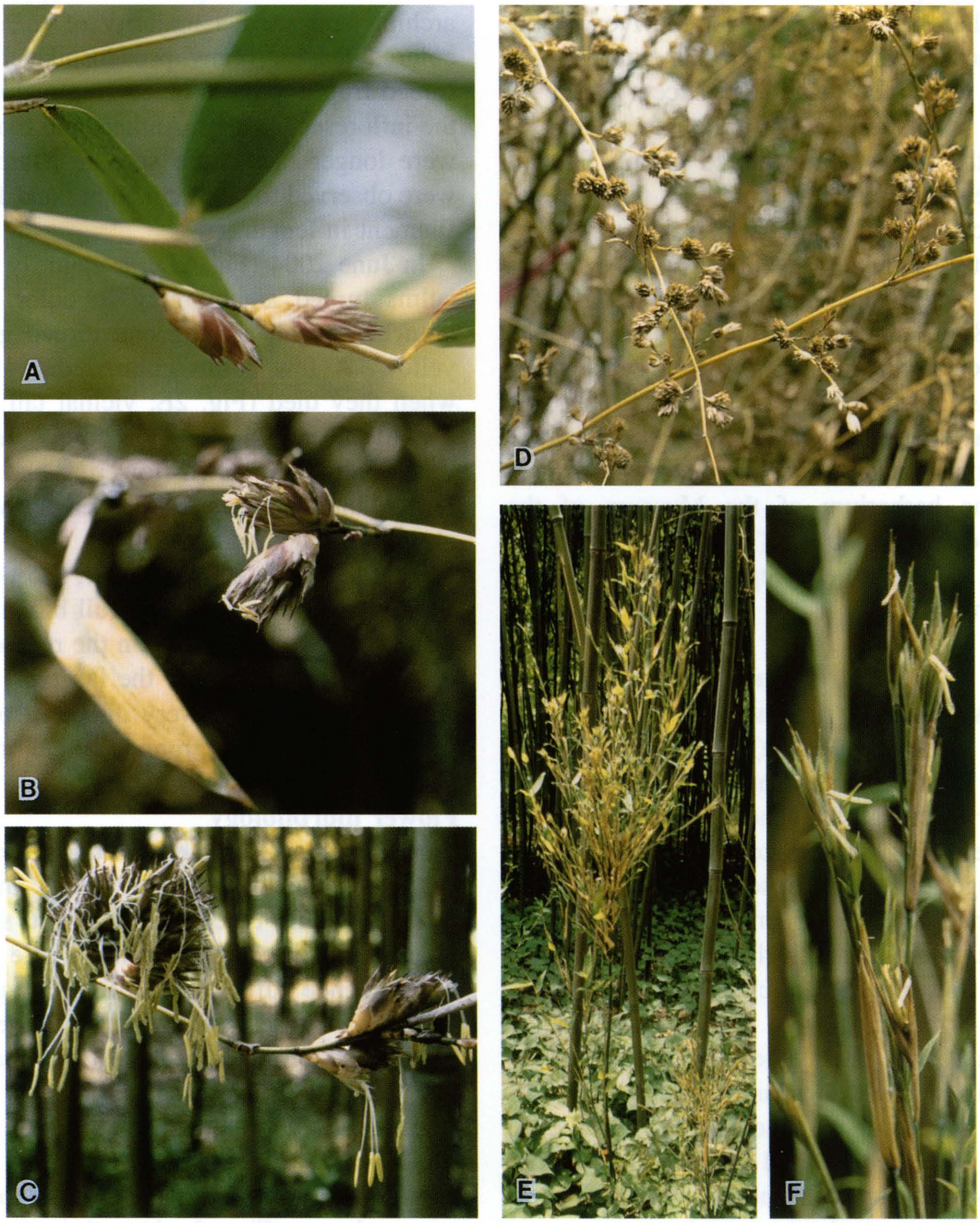

Fig. 2. Field photographs of inflorescences of *Phyllostachys meyeri*. A: large flower buds with deep green foliage leaves on February 21, 2004. B: inflorescence tufts under anthesis with yellowish foliage leaf on March 15, 2004. C: capitates in full-bloom on April 18, 2004. D: infructescences after flowering. E: a regenerated bamboo surrounded by dirty brown-colored dead culms. F: inflorescences of regenerated bamboo. D–F on June 27, 2004.

entirely glabrous, mostly maculate with smallish, smoky spots over the ivory-white surface of the sheath proper; auricles and oral setae not developed except rarely in very small culms (Fig. 1; on the right, six sheaths from a regenerated culm). Sheath-blades are linear and erect and the more or less crinkled in the upper part of the culm, or slightly crinkled. A sample was observed to have a culm-sheath proper and sheath blades of 38 cm and 23 cm in length (Fig. 1). The collected rhizome portions of the flowering culms (Hisamoto & Kobayashi 346) showed characteristic air canals on the transverse section. Voucher specimens are maintained in the herbarium of the Museum of the University of Tokyo (TI) and the Utsunomiya University, Department of Forest Science.

Results

Mass flowering process

In February 2004 (Fig. 2A), all culms were erect and verdant with a deep green color. Several branches were devoid of flower buds similar to a sterile chimera. Foliage leaves were also deep green in color and had a glossy upper surface. Apart from the chimera-like branches, all branch twigs bore flower buds at each node. Small to medium-sized buds were flesh-colored on the adaxial side and yellowish green on the abaxial side. Smaller buds were acute and 15 mm long, whereas medium to large-sized ones were fusiform and 17–19 mm long. The large-sized buds that measured 19 mm were slightly open at the apex.

In March 2004 (Fig. 2B), the culms remained deep green and erect, whereas all the foliage leaves had turned yellowish green and had begun to fall. The chimera-like branches observed in February bore a flower bud at each node on the twigs. Inflorescence tufts turned purple and opened to as anthesis with a 3 mm anther and an 8 mm filament.

In April 2004 (Fig. 2C), numerous culms turned a doll olive-green accompanied by arching and shed a majority of the straw-colored leaves. Many pseudospikelets protruded from the basal bracts in a majority of the inflorescence tufts. Anthers and filaments were longer than those seen in March and were observed to be 5 mm anther and 18 mm filament in length.

In June 2004 (Fig. 2D), a majority of the culms turned smoky gray in color, while branches began arching and turned grayish yellow. A few culms colored dirty brown when they died (Fig. 2E; vicinal tall culms behind central, slender, short culms). Inflorescence tufts completed flowering and transformed into capitates that opened further and revealed livid shading.

Thirteen culms of the slender, short regenerated bamboos emerged in full bloom (Fig. 2E). Inflorescences borne on the regenerated culms (Fig. 2F) were of the lax type or the spike type; these are very distinct from the capitate forms of tall, monocarpic culms.

Flower morphology

Measurements of the reproductive organs as well as the two types of culms; the tall, mass flowering types and the short, slender regenerated type are shown in Table 1. An inflorescence tuft in the mature stage had very short pedicels with several subtending bracts that formed a capitate (Figs. 3a, 4a). The detailed structure shows that the inflorescence tuft was held close at its base to the upper with two one-keeled prophylla (Figs. 3b–d), two bracts (Figs. 3e–f), two to three empty glumes (Figs. 3g–h) and three to four glumes with each pseudospikelet containing a few fertile florets (Figs. 3i–k). Glumes showed 12–19 nerves along with scattered transverse veinlets on the inner side.

An indeterminate inflorescence was composed of four primary ordered (McClure 1966) pseudospikelets each containing three to five sub-ordered pseudospikelets that were produced by subtended branchings. A fourth

Table 1. Morphological characters of reproductive organs of *Phyllostachys meyeri*

Floral part	Characters**	Mean/no./state	SD	Sample no.
Inflorescence	tuft length	17.3	1.37	121
	fertile pseudospikelet no.	12~20		
Floret	no. per pseudospikelet	4~5		
Gynoecium	stigma no.	3		
	node at style base	absent		
Androecium	stamen no.	3		
	anther length; March	3.1	0.33	27
	; April	5.2	0.55	23
	filament length; March	7.8	1.1	18
	; April	17.9	2.62	16
Lodicule*	no.	3		
	embryo side length	2.8	0.49	121
	hilum side	2.1	0.38	60
Palea*	length	7.2	1.01	61
	nerve no.	7	0.65	11
	inter-keels nerve no.	2	0.49	12
Lemma*	nerve no.	8	0.79	12
	length	8.2	0.96	61
Rachilla*	length	1.4	0.29	60
Caryopsis	diameter	1.7	0.2	294
	ovary length	3.4	0.37	294
	style length	1.6	0.29	293
	embryo length	0.9	0.16	61
Culm				
Monocarpic	height (cm)	502.5	72.6	4
	diameter	22.4	4.16	30
	internode length (cm)	22.1	6.05	75
Regenerated	height (cm)	80.5	33.5	11
	diameter	4.9	0.96	11
	internode length (cm)	12.6	4.89	70

*Size for florets in mature stage in June.
**Size in mm unless otherwise stated.

glume (related to Fig. 3j) contained three pseudospikelets (Fig. 3l), one of which (Fig. 3l, asterisk and m) (Figs. 3p–q) was removed to reveal five florets (Fig. 3n; A–E). A schematic of the branching system of a terminal pseudospikelet is shown in Fig. 3o; A–E represent the uppermost rudimental of the bottom floret. The terminal pseudospikelet had several thin bracts, and it was unclear whether these were ribbed glumes (Figs. 3p–r) or one-keeled prophylla (Figs. 3s–t).

A mature inflorescence tuft had 12–20 pseudospikelets, each of which had four to five florets (Table 1). Rachilla 1.4 mm in length, lemma 8.2 mm in length, villosus with approximately 8 nerves, palea villosus measured 7.2 mm in length with two inter-keel nerves, three lodicules, ciliated on upper margins with the embryo side measuring an average of 2.8 mm, and hilum side measuring 2.1 mm. Three stamens were studied where the anther and filament measured 5.2 mm and 17.9 mm, respectively. Three stigmas were studied; the node at the style base was absent. Caryopsis measured 1.7 mm in diameter and 3.4 mm in length with a style

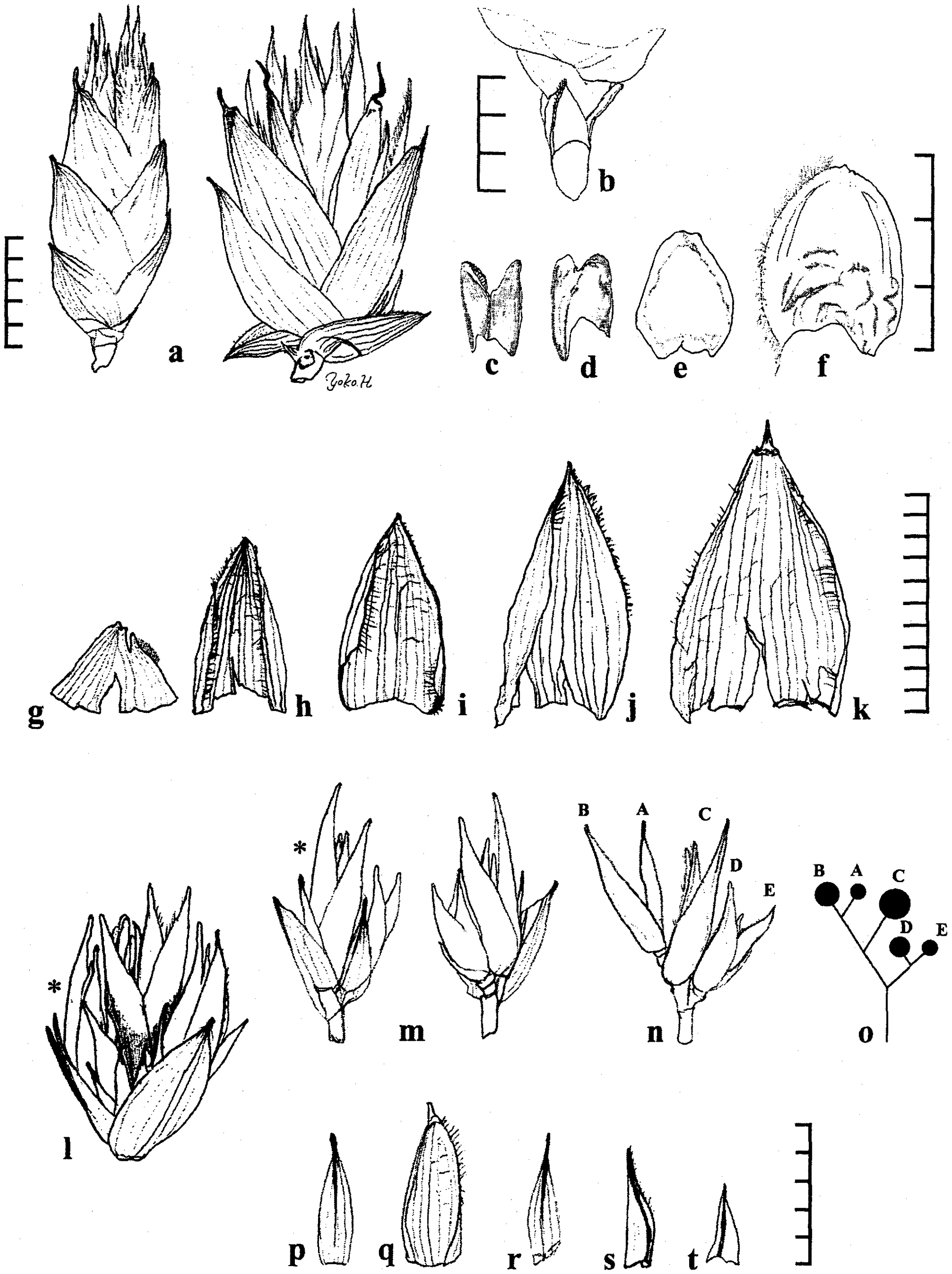

Fig. 3. Indeterminate inflorescences of *Phyllostachys meyeri*. a: immature tuft, opened to show each pseudospikelet (right). b–d: one-keeled prophylla. e, f: bracts; g–k: glumes. l: a pseudospikelet containing three sub-ordered pseudospikelets. Asterisk shows one pseudospikelet. m: one terminal pseudospikelet, abaxial view (left) and adaxial view (right). n: lower (p) and upper (q) glumes are removed to show five florets. o: schematic of branching system of (n). p–r: glumes; s,t: one-keeled prophylla. One division of each scale equals 1 mm.

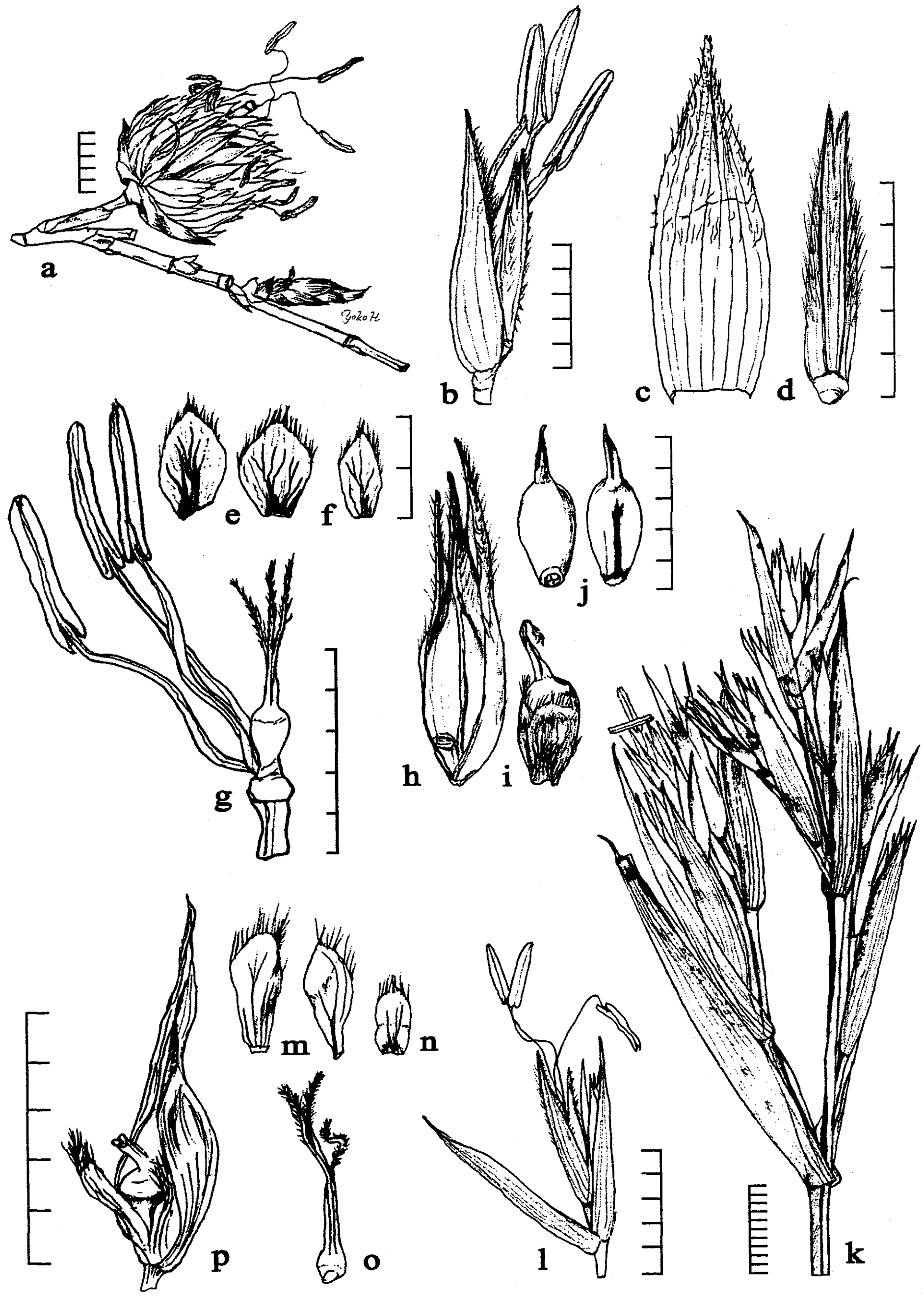

Fig. 4. Floral organs of *Phyllostachys meyeri*. a: mature capitate borne on the apex of a twig. b: floret in March, 2004. c: lemma; d: palea. e,f: embryo side and hilum side lodicules in March, 2004. g: androecium and gynoecium; h: dehisced floret in June. i: caryopsis with lodicules and stigma. j: caryopsis, embryo side (left) and hilum side (right). k–p: inflorescences, floret, lodicules, gynoecium and matured floret with lemma removed to show caryopsis of regenerated bamboo. One division of each scale equals 1 mm.

of 1.6 mm in length. The embryo was 0.9 mm in length and the hilum was linear.

The inflorescences of the regenerated bamboo (Fig. 4k) were of the lax or the spike types with no foliacous sheath-blade and were quite distinct from the tall monocarpic culms (Fig. 4a). The pedicels were oblong with the length of the florets, glumes, lodicules, and gynoecium being longer as compared to the capitate. However, the lemma, anther and caryopsis size were similar in length (Fig. 4p).

Discussion

The morphology of the capitate form and its indeterminate inflorescence structure described in the present study are apparently very similar to those of *Phyllostachys nidularia* Munro, which was introduced by McClure (1966). In addition, certain field photographs of mass flowering and honey-bee assisted pollination of *P. nidularia* (Huang et al. 2002) resemble our present observations. Further, we compared the morphology of culm-sheaths of *P. meyeri* with *P. nidularia* that was collected from a stand of the species located in the Fuji Bamboo Garden (Hisamoto & Kobayashi 350). The outer surface of the culm-sheaths was tinted ivory-white without any spots. The sheath-blade of *P. nidularia* is long, broadly triangular, and acuminate bearing broad, lobe-spreading auricles with slightly fringed margins. Thus, these characters are quite distinctive from each other, and there is no room to mistake *P. meyeri* for *P. nidularia*.

A description of flower morphology, along with a drawing of *P. meyeri* appeared in Geng and Wang (1996). The drawing of a peduncle described the measurement of the floral parts which coincide with our results on the exact inflorescences of the lax type and floral organs of the regenerated culms (Figs. 2E, F, 4k–p).

In China the genus *Phyllostachys* comprises 61 species (Geng and Wang 1996) in which 43 species including *P. meyeri* belong to section Phyllostachys and 18 to section Heteroclada.

Renvoize and Hodkinson (1997) as well as Gielis et al. (1997), and Hodkinson et al. (2000) examined the phylogenetic relationship among the congeneric species of *Phyllostachys* by means of molecular data analyses. They both applied the classification of Wang et al. (1980a, 1980b) to the genus *Phyllostachys* revealing a list of contrastive diagnostic characters of the two infragenetic sections Phyllostachys and Heteroclada. In summary, sections Phyllostachys versus Heteroclada have the following contrasting diagnostic characters; culm-sheaths that are sparsely or densely spotted versus not spotted or sometimes very finely spotted; rhizome lacking air canals versus rhizome with air canals; inflorescence spike or lax types versus capitate; lemma length, 16–28 mm versus 7–15 mm; anther length, 7–15 mm versus 4–8 mm; spikelet length, 25–30 mm versus 15–20 mm (Gielis et al. 1997). Based on these criteria, *Phyllostachys meyeri* belongs to section Heteroclada.

Only one resolution that *Phyllostachys meyeri* is a component of section Heteroclada of the genus *Phyllostachys* was shown with a UPGMA based on RAPD by Gielis et al. (1997). Other molecular analyses of the genus have not included *P. meyeri*. Further molecular study, including *P. meyeri*, using is expected.

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久本洋子[a]，柏木治次[b]，小林幹夫[a]：富士竹類植物園に植栽されたモウハイチク（イネ科タケ亜科）の一斉開花と花の形態

2004年２月から６月にかけ，静岡県にある富士竹類植物園に植栽されたモウハイチク *Phyllostachys meyeri* が一斉開花枯死を起こした．モウハイチクは1945年に McClure により，稈鞘などの栄養器官の形態に基づいて記載され，Wang らによって Phyllostachys 節に分類された．これまで，本種における花の形態は報告されてこなかったので，一斉開花・枯死の経過とともに有性生殖器官に関する詳細な記載を行った．モウハイチクの花序は花梗が極めて短く数次の分枝を繰り返して形成される多数の擬小穂から成る頭花状の無限花序であった．擬小穂，外穎，おしべの平均長はそれぞれ，9 mm，8.2 mm および 5.2 mm であった．また，一斉開花終了時に細く丈の低い再生竹が生じ，全ての枝に花梗が著しく伸長した穂状花序を付けていた．しかし，この花は，頭花状の花序を構成する花器官に比べ，小花，めしべ，鱗被の長さが若干長いものの，外穎やおしべの長さは等しいかやや短く，また，苞穎には目立った葉片は見られなかった．一斉開花中のモウハイチクの稈鞘は葉片が線形で長く，表面には細かい水玉模様が散在した．また地下茎の断面には輪生状に空隙が見られた．これらの形質は，従来の知見に反し，モウハイチクが Heteroclada 節に属することを示した．

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